Research Square

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Unveiling the complexity of the electrocardiographic and echocardiographic characteristics of heart failure: A tertiary care center's perspective

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Abstract

Background

Electrocardiography (ECG) and echocardiography (Echo) are fundamental and complementary modalities for the diagnosis and management of heart failure (HF). However, data describing their combined clinical and prognostic characteristics in patients with HF remain limited.

Methods

This retrospective observational study included 825 patients with HF. Comprehensive ECG and Echo parameters were compared, and multivariable logistic regression was performed to identify independent predictors of in-hospital mortality.

Results

HF with reduced ejection fraction (HFrEF) was the most frequent phenotype (55.4%). Male patients exhibited significantly higher frequencies of right bundle branch block and left anterior fascicular block (11.6%, $P = 0.037$; and 23.9%, $P = 0.001$, respectively), whereas female patients had a higher burden of valvular abnormalities, including mitral stenosis (7.1%, $P < 0.001$) and tricuspid regurgitation (14.6%, $P = 0.005$). Sinus rhythm was most common in HFrEF (74.3%, $P = 0.002$), whereas atrial fibrillation was most prevalent in HF with mildly reduced ejection fraction (HFmrEF) (38.8%, $P = 0.003$). On echocardiography, HFrEF was associated with the greatest left ventricular dilation ($P < 0.001$), whereas HFmrEF and HF with preserved ejection fraction (HFpEF) showed more pronounced markers of concentric remodeling. Multivariable logistic regression identified left bundle branch block, moderate-to-severe aortic stenosis, severe tricuspid regurgitation, and right ventricular dysfunction as independent predictors of in-hospital mortality ($P < 0.05$).

Conclusion

HF is characterized by distinct electrical and structural features that vary according to sex and LVEF. These findings support an integrated diagnostic approach that combines electrical and structural data to improve risk stratification in patients with HF.

1. Introduction

Electrocardiography (ECG) and echocardiography (Echo) are fundamental and complementary modalities for the diagnosis and management of cardiovascular disease [1]. ECG provides valuable information on cardiac electrical activity, conduction patterns, rhythm disturbances, ischemic changes, and findings suggestive of ventricular hypertrophy [2]. Echo, in contrast, enables dynamic assessment of

cardiac structure and function through direct evaluation of chamber dimensions, wall motion and thickness, valvular stenosis and regurgitation, congenital heart defects, and overall systolic and diastolic performance [3]. Together, these noninvasive modalities play a central role in diagnosing the multifaceted syndrome of heart failure (HF) and guiding therapeutic decision-making [4].

Growing evidence underscores the complementary diagnostic and prognostic value of ECG and Echo in identifying electrophysiological abnormalities and structural cardiac changes in HF. Left bundle branch block (LBBB) and atrial fibrillation (AFib) are important ECG findings that may contribute to mechanical dyssynchrony and reduced left ventricular ejection fraction (LVEF), as demonstrated on Echo [5, 6]. Echocardiographic parameters such as diastolic dysfunction, left atrial enlargement, left ventricular hypertrophy, and elevated left ventricular filling pressure reflect myocardial remodeling and hemodynamic burden [7]. These markers are often detected before overt clinical decompensation, thereby providing important insight into HF phenotypes and informing clinical management [8].

Despite the routine use of ECG and Echo in clinical practice, data describing their combined characteristics across diverse HF populations remain limited, particularly in the Middle East, where comorbidities are common, and disease presentation is often advanced. Specific ECG and Echo features have important implications for diagnosis, risk stratification, and management in HF [1]. This study aimed to characterize ECG and Echo abnormalities in patients with HF and to provide a comprehensive evaluation of their diagnostic and prognostic significance in a high-risk population.

2. Materials and methods

2.1. Patients and data collection

This retrospective observational study included 825 inpatients with a primary hospital discharge diagnosis of HF at the Beirut Cardiac Institute (BCI), a tertiary medical center in Lebanon, from January 2020 to December 2023. Clinical data were retrieved from the archived medical records at BCI. The inclusion criteria were patients 18 years and older, a confirmed HF diagnosis, and complete medical records. The exclusion criteria were pregnancy, cardiac surgeries performed 3 months before screening, and other comorbidities that could change ECG and Echo results.

ECG variables records included: electrical rhythm, left bundle branch block (LBBB), right bundle branch block (RBBB), second and third degree atrioventricular block, left anterior fascicular block (LAFB), and premature ventricular contractions (PVCs). On the other hand, the Echo features of HF consisted of: left atrium (LA) diameter, left ventricular end diastolic diameter (LVEDD), intraventricular septum diameter (IVS), left ventricular posterior wall thickness (LVPW), enlarged left ventricular (LV), right ventricular (RV) dysfunction, dilated RV, aortic regurgitation, aortic stenosis, mitral regurgitation, mitral stenosis, tricuspid valve regurgitation, pulmonary artery pressure (PAP), and pericardial effusion. In-hospital mortality was included regardless of whether the death had occurred during the first admission or subsequent admissions. The study was evaluated and approved by the BCI Institutional Review Board (Approval

code: 5/2024). The study was conducted in accordance with the Declaration of Helsinki, and informed consent was waived due to its retrospective design.

2.2. Statistical analysis

SPSS version 24 (SPSS Inc., Chicago, Illinois, USA) software package was used to analyze all data. Categorical variables were presented as frequency and percentage. Continuous variables were described as the mean and standard deviation for normally distributed data and as the median and interquartile range for skewed data. Data distribution was determined with the Shapiro-Wilk test. Differences between categorical variables were evaluated with Chi-square or Fisher's Exact tests if the number of observations in one category was below five. Differences between normally distributed quantitative parameters were determined using the two-sample t-test and the ANOVA test, while non-normally distributed quantitative data were analyzed using the Mann-Whitney U test and Kruskal-Wallis H test. A post hoc Bonferroni correction was applied to compare values between groups. A multivariate analysis was conducted to identify predictors of mortality. A two-sided p-value < 0.05 was considered statistically significant.

3. Results

The study included 825 patients with HF, of whom 502 (68%) were male. Most patients were in sinus rhythm (69.21%), with no statistically significant difference between males and females. There were also no significant sex-based differences in AFib, LBBB, second- and third-degree AV block, or PVCs. However, males had a higher frequency of RBBB (11.6% vs. 7.1%; $p = 0.037$) and LAFB (23.9% vs. 14.2%; $p = 0.001$) than females (Table 1).

Table 1
Electrocardiogram characteristics of heart failure patients based on sex distribution

Characteristic	Male (n = 502)	Female (n = 323)	*P*-value
ECG rhythm	353 (70.6)	218 (67.5)	0.345
Sinus	140 (28.0)	103 (31.9)	0.232
AFib			
LBBB	75 (14.9)	49 (15.2)	0.928
RBBB	58 (11.6)	23 (7.1)	0.037
AV block (2nd and 3rd degree)	23 (4.6)	13 (4.0)	0.702
LAFB	120 (23.9)	46 (14.2)	0.001
PVCs	65 (12.9)	45 (13.9)	0.685
Abbreviations: AFib: atrial fibrillation, LBBB: left bundle branch block, RBBB: right bundle branch block, AV: atrioventricular, LAFB: left anterior fascicular block, PVCs: premature ventricular contractions.			
$P < 0.05$ was considered statistically significant.			

Among the 825 patients with HF, 457 (55.4%) had HF with reduced ejection fraction (HFrEF), 252 (30.5%) had HF with preserved ejection fraction (HFpEF), and 116 (14.1%) had HF with mildly reduced ejection fraction (HFmrEF). ECG characteristics by the LVEF group are shown in Table 2. The frequency of AFib was significantly higher in the HFmrEF group (38.8%) than in the other groups ($p = 0.003$). Sinus rhythm was most common in HFrEF (74.3%), followed by HFpEF (64.7%) and HFmrEF (60.3%) ($p = 0.002$), mirroring the inverse pattern observed for AFib. LBBB and LAFB were more common in patients with HFrEF (19.0% and 25.4%, respectively), with statistically significant differences across HF groups ($P = 0.001$ and $P < 0.001$, respectively). RBBB, AV block, and PVCs did not differ significantly among HF groups.

Table 2
Electrocardiogram characteristics of heart failure patients based on LVEF groups

Characteristic	HFrEF (≤ 40%) (n = 457)	HFmrEF (41–49%) (n = 116)	HFpEF (≥ 50%) (n = 252)	Overall *P*-value
ECG rhythm	338 (74.3)[a]	70 (60.3)[b]	163 (64.7)[b]	0.002
Sinus	113 (24.8)[a]	45 (38.8)[b]	85 (33.7)[b]	0.003
AFib				
LBBB	87 (19.0)[a]	14 (12.1)[a,b]	23 (9.1)[b]	0.001
RBBB	44 (9.6)	7 (6.0)	30 (11.9)	0.205
AV block (2nd and 3rd degree)	21 (4.6)	3 (2.6)	12 (4.8)	0.680
LAFB	116 (25.4)[a]	19 (16.4)[a, b]	31 (12.3)[b]	< 0.001
PVCs	64 (14.0)	12 (10.3)	34 (13.5)	0.604

Abbreviations: AFib: atrial fibrillation, LBBB: left bundle branch block, RBBB: right bundle branch block, AV: atrioventricular, LAFB: left anterior fascicular block, PVCs: premature ventricular contractions.

P < 0.05 was considered statistically significant.

Different superscript letters ([a], [b],[c])within a row indicated a significant pairwise difference (*p* < 0.05) based on Bonferroni-adjusted post-hoc comparison. Groups sharing a common letter are not significantly different.

Echocardiographic characteristics according to sex are presented in Table 3. Males had a significantly larger LA diameter (4.81 ± 0.93 cm vs. 4.65 ± 0.98 cm, *P* = 0.026) and LVEDD (5.88 ± 1.11 cm vs. 5.13 ± 0.95 cm, *P* < 0.001), as well as higher rates of enlarged LV (62.0% vs. 35.9%, *P* < 0.001) and RV dysfunction (22.9% vs. 15.8%, *P* = 0.013). In contrast, females showed higher frequencies of moderate-to-severe mitral valve stenosis (7.1% vs. 1.2%, *P* < 0.001) and severe tricuspid valve regurgitation (14.6% vs. 8.4%, *P* = 0.005). No statistically significant sex-based differences were observed for IVS diameter, LVPW thickness, dilated RV, aortic valve regurgitation or stenosis, mitral valve regurgitation, or PAP.

Table 3
Echocardiogram characteristics of heart failure patients based on sex distribution

Characteristic	Male (n = 502)	Female (n = 323)	*P*-value
LA diameter (cm)	4.81 ± 0.93	4.65 ± 0.98	0.026
LVEDD (cm)	5.88 ± 1.11	5.13 ± 0.95	< 0.001
IVS diameter [IQR] (cm)	1.10 [1.00-1.30]	1.20 [1.00-1.30]	0.399
LVPW thickness [IQR] (cm)	1.00 [0.90–1.20]	1.00 [0.9–1.20]	0.626
Enlarged LV	311 (62.0)	116 (35.9)	< 0.001
Moderate-to-severe aortic valve regurgitation	31 (6.2)	25 (7.7)	0.383
Moderate-to-severe aortic valve stenosis	49 (9.8)	45 (13.9)	0.066
Moderate-to-severe mitral valve regurgitation	119 (23.7)	89 (27.6)	0.214
Moderate-to-severe mitral valve stenosis	6 (1.2)	23 (7.1)	< 0.001
Severe tricuspid valve regurgitation	42 (8.4)	47 (14.6)	0.005
RV dysfunction	115 (22.9)	51 (15.8)	0.013
Dilated RV	109 (21.7)	59 (18.3)	0.230
PAP (mmHg)	44.87 ± 15.19	45.76 ± 14.30	0.484
Abbreviation: LA: left atrium, LVEDD: left ventricular end diastolic diameter, IVS: intraventricular septum diameter, IQR: interquartile range, LVPW: left ventricular posterior wall, LV: left ventricle, RV: right ventricular, PAP: pulmonary artery pressure.			
P < 0.05 was considered statistically significant.			

Analysis of echocardiographic characteristics across HF groups revealed marked structural and functional differences (Table 4). Consistent with the underlying pathophysiology of HF, patients with HFrEF had the largest LVEDD (6.14 ± 1.0 cm; *P* < 0.001) and the highest frequencies of enlarged LV (74.4%; *P* < 0.001) and RV dysfunction (24.3%; *P* = 0.004). They also had the lowest IVS diameter (1.10 [0.90–1.20], *P* < 0.001) and LVPW thickness (1.00 [0.80–1.10], *P* < 0.001). In contrast, HFmrEF was associated with a significantly higher rate of functional aortic valve regurgitation (13.8%; *P* = 0.002). Patients with HFpEF had the highest frequencies of aortic valve stenosis (16.7%; *P* = 0.001), mitral valve stenosis (6.7%; *P* < 0.001), and severe tricuspid valve regurgitation (15.9%; *P* = 0.016), but the lowest frequency of mitral regurgitation (15.9%, *P* < 0.001).

Table 4
Echocardiogram characteristics of heart failure patients based on LVEF groups

Characteristic	HFrEF (≤ 40%) (n = 457)	HFmrEF (41–49%) (n = 116)	HFpEF (≥ 50%) (n = 252)	Overall *P*-value
LA diameter (cm)	4.78 ± 0.90	4.87 ± 0.87	4.64 ± 1.04	0.083
LVEDD (cm)	6.14 ± 1.0[a]	5.40 ± 0.76[b]	4.67 ± 0.76[c]	< 0.001
IVS diameter [IQR] (cm)	1.10 [0.90–1.20][a]	1.20 [1.00-1.40][b]	1.20 [1.10–1.40][b]	< 0.001
LVPW thickness [IQR] (cm)	1.00 [0.80–1.10][a]	1.10 [1.00-1.25][b]	1.10 [0.90–1.20][b]	< 0.001
Enlarged LV	340 (74.4)[a]	53 (45.7)[b]	52 (20.6)[c]	< 0.001
Moderate-to-severe aortic valve regurgitation	30 (6.6)[a]	16 (13.8)[b]	10 (4.0)[a]	0.002
Moderate-to-severe aortic valve stenosis	38 (8.3)[a]	14 (12.1)[a,b]	42 (16.7)[b]	0.001
Moderate-to-severe mitral valve regurgitation	133 (29.1)[a]	35 (30.2)[a,b]	40 (15.9)[b]	< 0.001
Moderate-to-severe mitral valve stenosis	6 (1.3)[a]	6 (5.2)[b]	17 (6.7)[b]	0.001
Severe tricuspid valve regurgitation	40 (8.8)[a]	10 (8.6)[a,b]	39 (15.9)[b]	0.016
RV dysfunction	111 (24.3)[a]	17 (14.7)[a,b]	38 (15.1)[b]	0.004
Dilated RV	97 (21.2)	17 (14.7)	54 (21.4)	0.254
PAP (mmHg)	44.56 ± 15.22	44.42 ± 13.09	45.03 ± 14.91	0.214

Abbreviation: LA: left atrium, LVEDD: left ventricular end diastolic diameter, IVS: intraventricular septum diameter, IQR: interquartile range, LVPW: left ventricular posterior wall, LV: left ventricle, RV: right ventricular, PAP: pulmonary artery pressure.

P < 0.05 was considered statistically significant.

Different superscript letters ([a], [b])within a row indicated a significant pairwise difference ($p < 0.05$) based on Bonferroni-adjusted post-hoc comparison. Groups sharing a common letter are not significantly different.

Evaluation of the prognostic value of ECG and Echo parameters identified several significant predictors of in-hospital mortality (Table 5). In the univariate analysis, LBBB (OR = 1.67, 95% CI [1.13–2.48], *P* = 0.010), moderate-to-severe aortic valve stenosis (OR = 1.84, 95% CI [1.19–2.85], *P* = 0.006), severe tricuspid regurgitation (OR = 2.28, 95% CI [1.46–3.55], *P* < 0.001), and RV dysfunction (OR = 2.02, 95% CI [1.42–2.87], *P* < 0.001) were significantly associated with higher odds of in-hospital mortality. After

adjustment for potential confounders, multivariable logistic regression confirmed that LBBB (OR = 1.65, 95% CI [1.09–2.51], *P* = 0.017), moderate-to-severe aortic valve stenosis (OR = 1.62, 95% CI [1.02–2.06], *P* = 0.041), severe tricuspid regurgitation (OR = 1.74, 95% CI [1.07–2.82], *P* = 0.025), and RV dysfunction (OR = 1.75, 95% CI [1.20–2.56], *P* = 0.004) were independent predictors of in-hospital mortality.

Table 5
Univariate and Multivariate logistic regression for predictors of in-hospital mortality

Characteristics	n = 825	Univariate logistic regression		Multivariate logistic regression	
		OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
AFib	243 (29.5)	1.23 (0.89,1.69)	0.203	1.17 (0.79,1.57)	0.526
LBBB	124 (15.0)	1.67 (1.13,2.48)	0.010	1.65 (1.09,2.51)	0.017
RBBB	81 (9.8)	1.05 (0.64,1.71)	0.846	1.03 (0.61,1.72)	0.908
1st and 2nd AV block	36 (4.4)	1.43 (0.71,2.84)	0.308	1.26 (0.60,2.66)	0.537
LAFB	166 (20.1)	1.24 (0.86,1.77)	0.239	1.20 (0.81,1.76)	0.347
PVCs	110 (13.3)	0.76 (0.48,1.20)	0.245	0.76 (0.47,1.21)	0.254
EF ≤ 40%	457 (55.4)	1.13 (0.84,1.53)	0.394	1.08 (0.78,1.50)	0.612
Moderate-to-severe aortic valve regurgitation	56 (6.8)	1.59 (0.91,2.77)	0.099	1.41 (0.78,2.57)	0.251
Moderate-to-severe aortic valve stenosis	94 (11.4)	1.84 (1.19,2.85)	0.006	1.62 (1.02,2.60)	0.041
Moderate-to-severe mitral valve regurgitation	208 (25.2)	1.38 (0.99,1.93)	0.053	1.13 (0.79,1.61)	0.502
Moderate-to-severe mitral valve stenosis	29 (3.5)	1.83 (0.87,3.88)	0.110	1.49 (0.67,3.29)	0.320
Severe tricuspid valve regurgitation	89 (10.8)	2.28 (1.46,3.55)	< 0.001	1.74 (1.07,2.82)	0.025
RV dysfunction	166 (20.1)	2.02 (1.42,2.87)	< 0.001	1.75 (1.20,2.56)	0.004

Abbreviation: AFib: Atrial fibrillation, AV block: atrioventricular block, EF: Ejection fraction, LAFB: left anterior fascicular block, LBBB: left bundle branch block, RBBB: right bundle branch block, PVCs: premature ventricular contractions, RV: right ventricle.

P < 0.05 was considered statistically significant.

4. Discussion

In this study, the clinical presentation of HF, as reflected by ECG and Echo findings, was heterogeneous. Sex-based assessment demonstrated clear differences in both electrical and structural presentation. Although no sex differences were observed in sinus rhythm, AFib, LBBB, or PVCs [9–11], RBBB and LAFB were more common in males, suggesting a greater burden of conduction delay in male patients with HF. These electrical differences may reflect sex-related physiological variation that contributes to distinct patterns of electrical dyssynchrony in HF [12, 13].

These differences in electrical conduction were paralleled by structural differences on Echo. Males had larger LA diameter and LVEDD, as well as higher frequencies of enlarged LV and RV dysfunction, suggesting greater chamber dilation and more advanced contractile impairment [9, 14, 15]. In contrast, females showed a higher burden of valvular pathology, suggesting that HF in women may be more closely associated with valvular dysfunction than with primary chamber dilation. These findings are consistent with international reports indicating that women with HF more often present with valvular impairment [10, 14]. Together, these observations underscore the importance of sex-specific ECG and Echo assessment in HF, particularly because valvular disease can substantially influence hemodynamic burden and clinical management.

Our findings also suggest that electrical abnormalities vary according to HF phenotype. Although sinus rhythm predominated in the HFrEF group, AFib was more common in HFmrEF and HFpEF, indicating potentially different arrhythmogenic mechanisms across LVEF categories. This pattern contrasted with previous reports in which AFib was more strongly associated with advanced left ventricular dilation [2, 6, 16–18]. However, it is consistent with emerging evidence from the Middle East suggesting that AFib may represent a prominent comorbid feature in patients with mildly reduced or preserved EF [19]. In addition, conduction abnormalities such as LBBB and LAFB were more frequent in HFrEF, supporting their role as markers of advanced ventricular dysfunction and poorer prognosis in HF [2, 20, 21].

Patients with HFrEF exhibited the most pronounced LV dilation, reflected by the largest LVEDD and the highest frequency of enlarged LV, consistent with eccentric remodeling and advanced systolic dysfunction [22, 23]. RV dysfunction was also significantly associated with HFrEF, supporting the concept that left-sided HF often progresses to involve right ventricular impairment [24]. In contrast, HFmrEF and HFpEF were characterized by greater IVS diameter and LVPW thickness, suggesting a predominance of concentric remodeling [22, 23].

Our study further revealed distinct distributions of valvular abnormalities across LVEF groups. HFmrEF was associated with higher frequencies of functional aortic and mitral regurgitation, suggesting an intermediate stage of myocardial remodeling with evolving changes in LV geometry, in line with previous studies [25–27]. By contrast, HFpEF was characterized by higher rates of aortic and mitral stenosis [28, 29], as well as severe tricuspid regurgitation, as previously reported [30]. Valvular stenosis may influence LV hemodynamics and contribute to progressive fluid overload [31–33], while also promoting electrical remodeling that may predispose patients to AFib and other conduction abnormalities [34].

Finally, our study identified LBBB, moderate-to-severe aortic valve stenosis, severe tricuspid valve regurgitation, and RV dysfunction as independent predictors of in-hospital mortality. The prognostic importance of these markers is supported by previous cardiovascular studies demonstrating their association with poorer outcomes and increased mortality [35–38]. These findings emphasize the importance of moving beyond LVEF alone and incorporating specific ECG and Echo parameters into risk assessment models for HF.

A major strength of this study is its large sample size, which provides valuable data on the HF population in a region where combined ECG and Echo data remain limited. It offers a detailed profile of patients with HF in the Middle East, a population that is often underrepresented in global cardiovascular registries.

This study was conducted at a tertiary cardiac care center, where patients are typically at higher risk, which may explain the greater frequency of electrical, structural, and functional abnormalities compared with studies from primary or secondary care settings. In addition, the analysis focused on in-hospital mortality, regardless of whether death occurred during the index admission or a subsequent admission. The absence of long-term post-discharge follow-up limited our ability to assess the effect of ECG and Echo abnormalities on long-term survival.

5. Conclusion

This study provides a detailed characterization of ECG and Echo features in patients with HF at a tertiary cardiac care center in the Middle East. The findings highlight the complexity of HF, in which electrical instability, structural remodeling, and functional impairment are closely interconnected. Although HFrEF was the most common phenotype, characterized by marked chamber dilation and conduction delay, HFmrEF and HFpEF exhibited distinct profiles, with a higher burden of valvular disease and hypertrophic remodeling.

Importantly, identifying LBBB, moderate-to-severe aortic stenosis, severe tricuspid regurgitation, and RV dysfunction as independent predictors of in-hospital mortality broadens risk assessment beyond a solely left-sided perspective. These findings indicate that prognosis in HF is more accurately captured by integrating electrical markers of dyssynchrony with structural indicators of right-sided dysfunction and valvular disease.

Consistent use of ECG and Echo remains essential for accurate risk assessment. In high-acuity settings, particularly in the Arab region where HF often presents at an advanced stage, clinicians should look beyond EF and consider these independent predictors in routine evaluation. Future studies should incorporate long-term follow-up to determine how acute electrical and structural markers influence survival over time and whether early targeted interventions can reduce the mortality risk associated with these abnormalities.

Abbreviations

AFib
Atrial fibrillation
AV
Atrioventricular
HFmrEF
Heart failure with mildly reduced ejection fraction
HFpEF
Heart failure with preserved ejection fraction
HFrEF
Heart failure with reduced ejection fraction
IVS
Intraventricular septum diameter
LA
Left atrium
LAFB
Left anterior fascicular block
LBBB
Left bundle branch block
LV
Left ventricle
LVEDD
Left ventricular end diastolic diameter
LVPW
Left ventricular posterior wall
RBBB
Right bundle branch block
RV
Right ventricular
PAP
Pulmonary artery pressure
PVCs
Premature ventricular contractions

Declarations

Institutional Review Board Statement

This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Beirut Cardiac Institute, Beirut, Lebanon

Informed Consent Statement: Patient consent was waived due to the retrospective nature of the study.

Conflicts of Interest:

The authors declare no competing interests.

Author Contribution

Z.S.: Conceptualization, Data Curation, Project Administration, Formal Analysis, Investigation, Methodology, Visualization, Writing – original draft. M.H.: Data Curation, Investigation, Methodology, Visualization, Validation. F.A.S.: Supervision, Data Analysis, Writing – review and editing. A.R.: Resources, Conceptualization, Investigation, Supervision, Validation, Writing – review and editing.

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Data Availability Statement:

Data are contained within the article, and further inquiries can be directed to the corresponding author.

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